The CMS Outer Tracker Upgrade for the High Luminosity LHC

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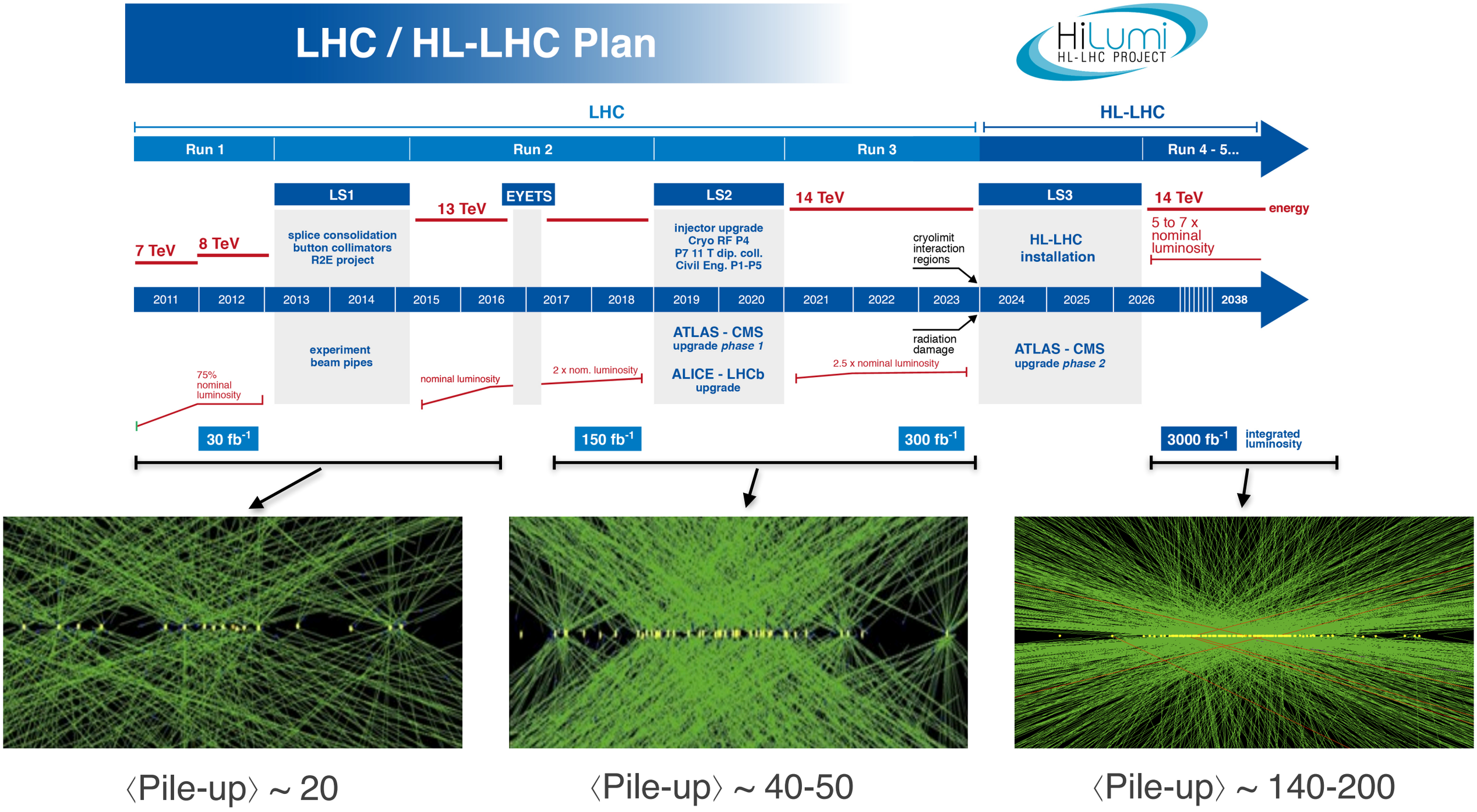
Toward the HL-LHC Upgrade



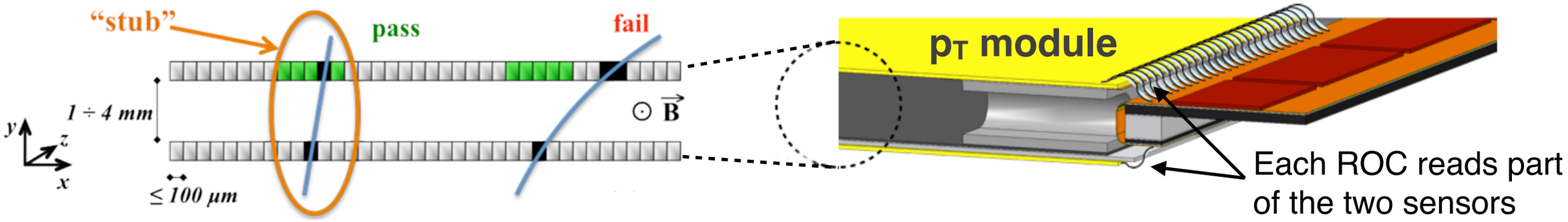
⟨Pile-up⟩ ~ 20

⟨Pile-up⟩ ~ 40-50

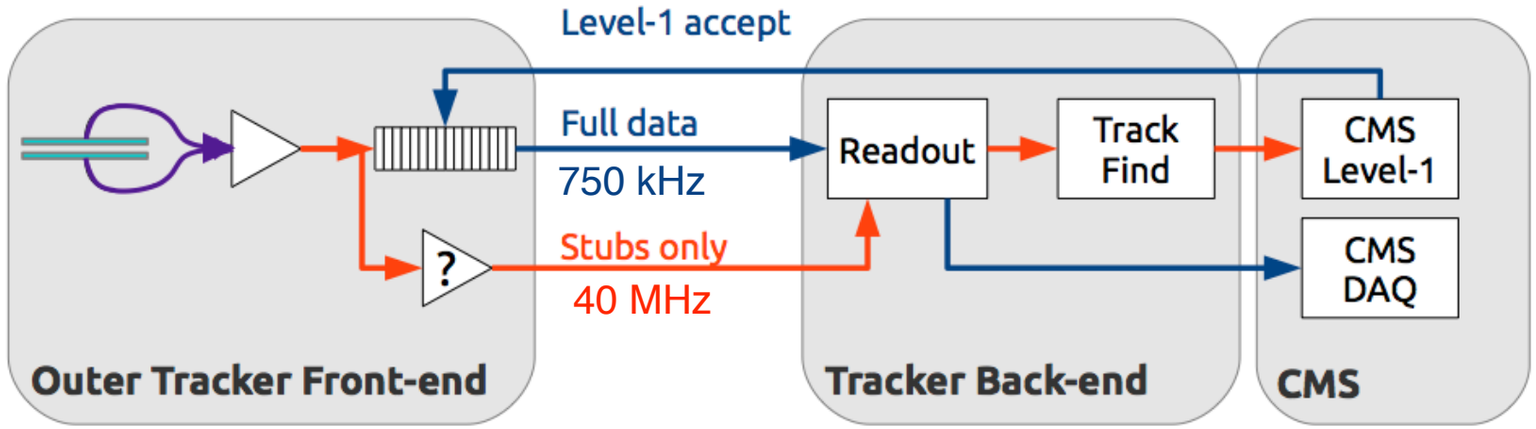
⟨Pile-up⟩ ~ 140-200

The p_T-module concept

Thanks to its 3.8T magnetic field, CMS capable of selecting tracks with p_T>1 at L1-trigger.

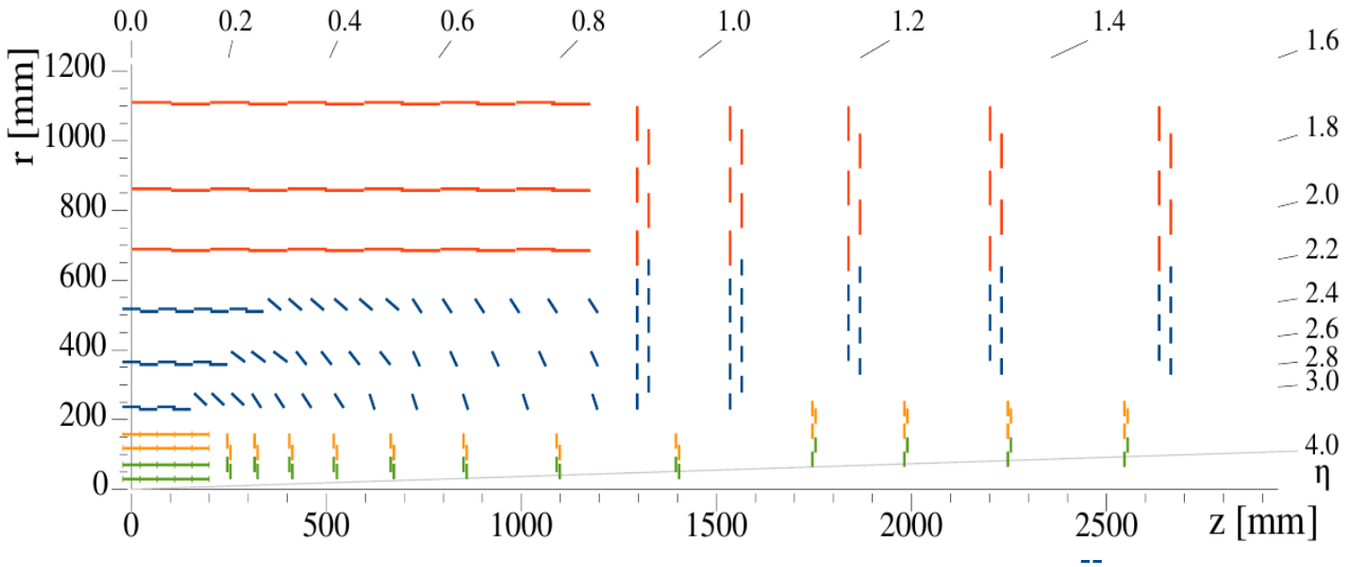


Stubs processed in the back-end electronics to build L1 track primitives at 40 MHz.



The CMS HL-LHC outer tracker will be equipped with two p_T module versions

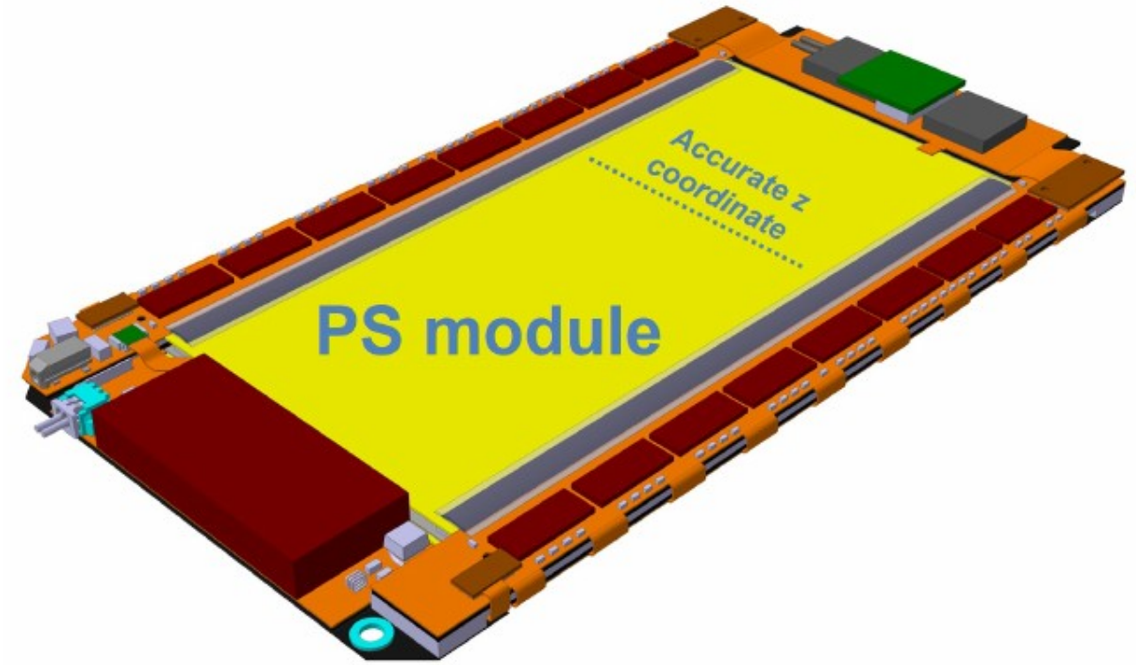
- **PS** (pixel + strip) modules r < 60 cm
- **2S** (strip + strip) modules r > 60 cm.

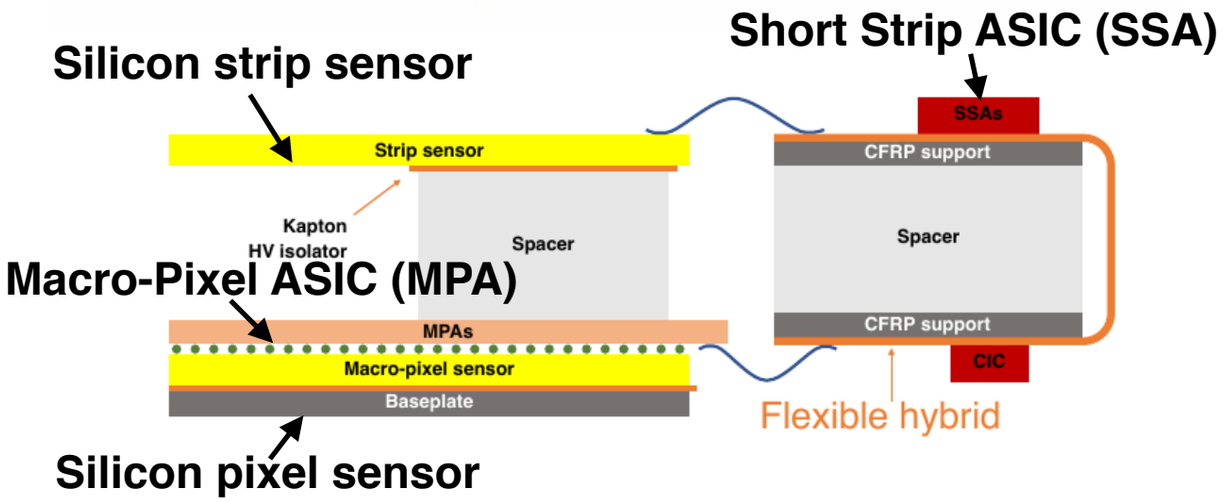


PS and 2S Modules

PS modules: Macro Pixel + Strip

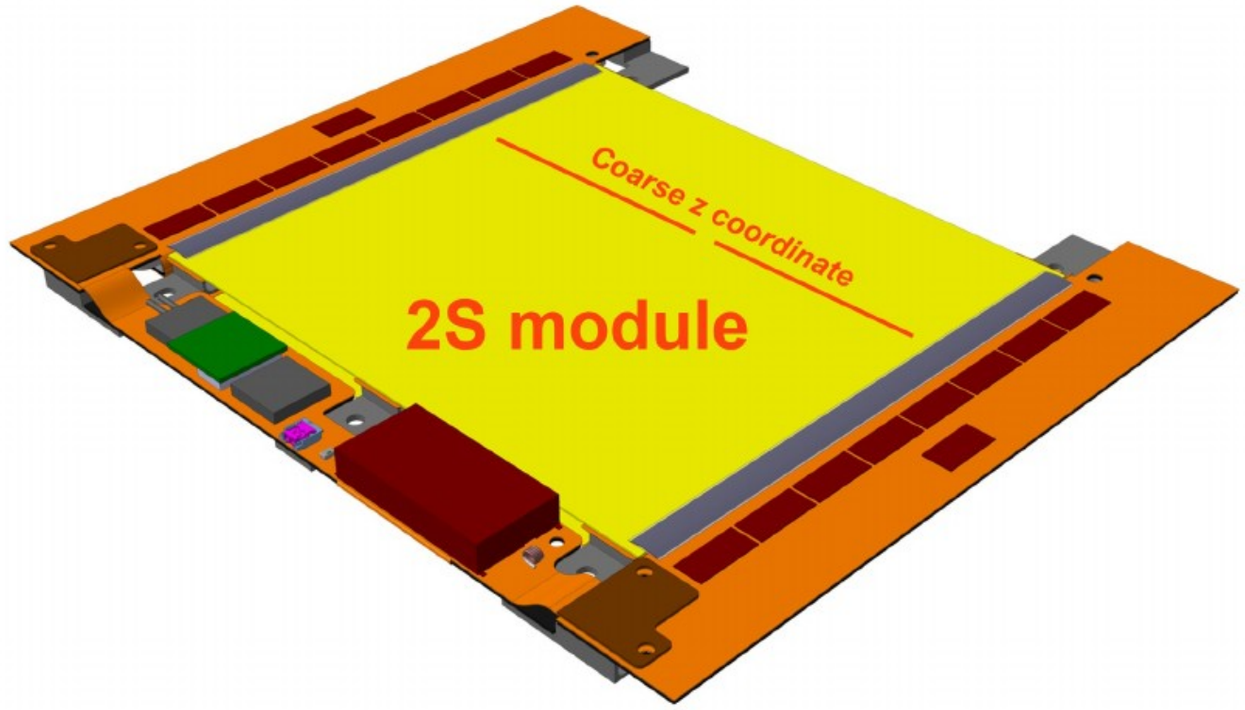
Macro Pixel: 1.5 mm × 100 μm
Strip: 2.4 cm × 100 μm
Module area: ~5 × 10 cm²

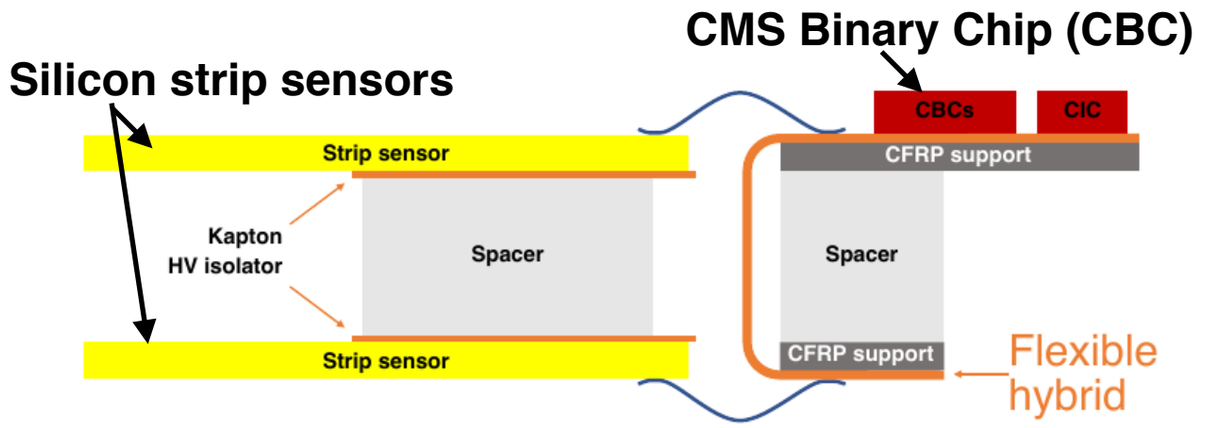




2S modules: Strip + Strip

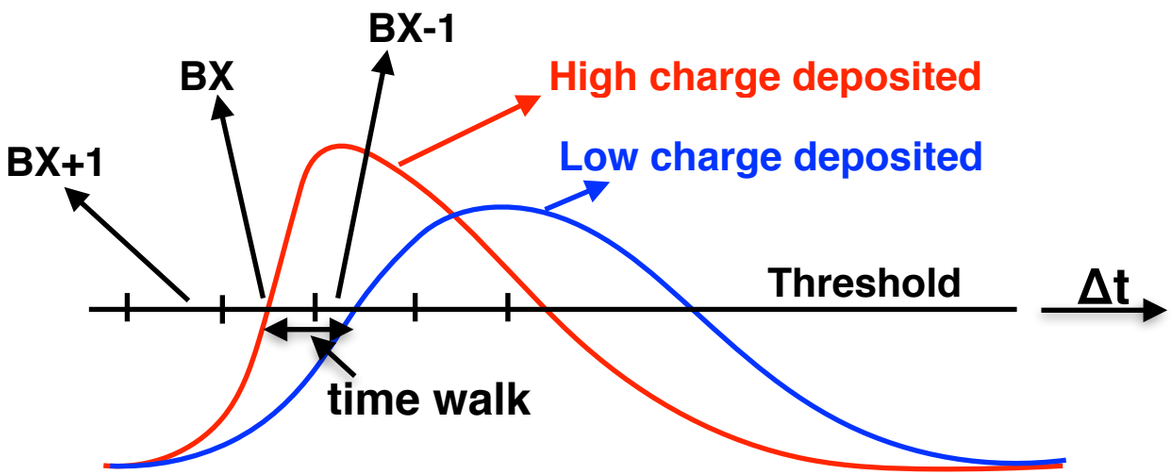
Strip: 5 cm × 90 μm (both sides)
Module area: ~10 × 10 cm²

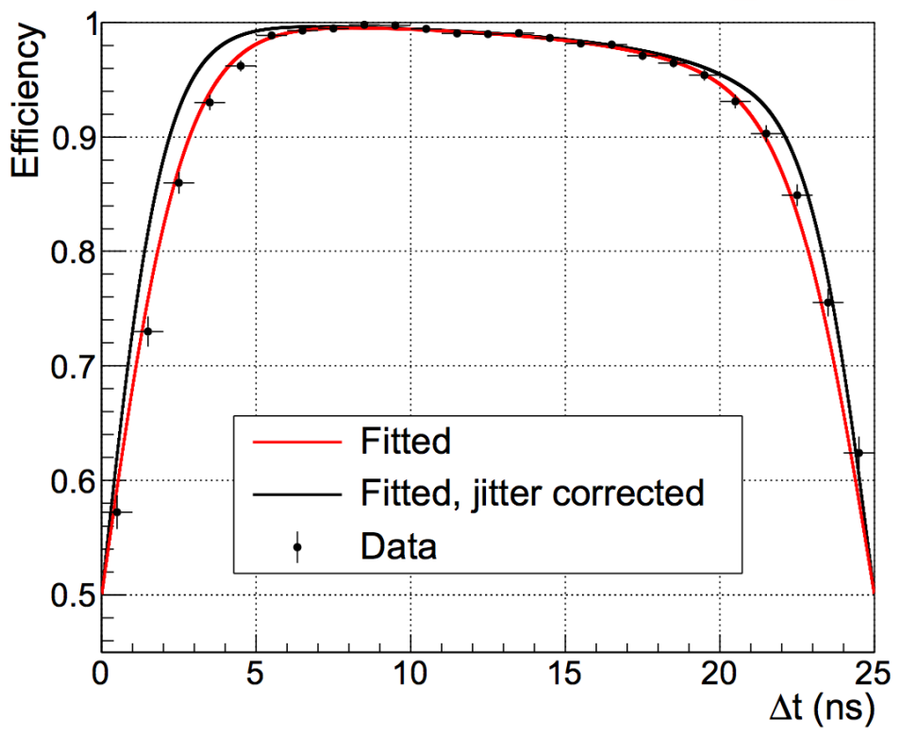




Status of the upgrade - PS prototypes

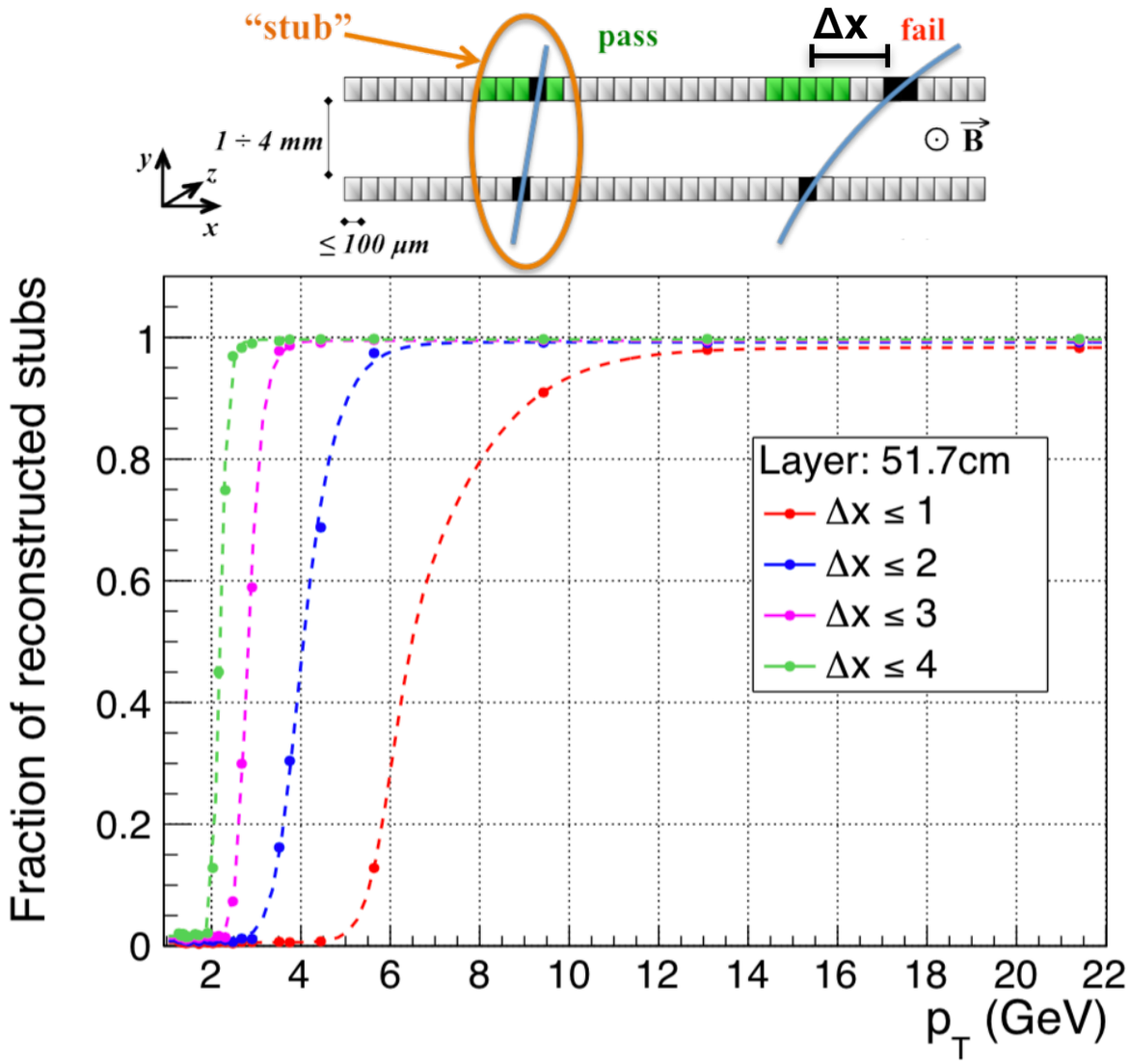
First MPA prototypes produced and mini-pixel-modules (3x2) MPAs assembled and their functionalities tested on beam.





- Efficiency vs clock delay in agreement with the simulations

- Two MPAs stacked to validate the stubs.
- Track p_T simulated by tilting the module with respect to the beam.



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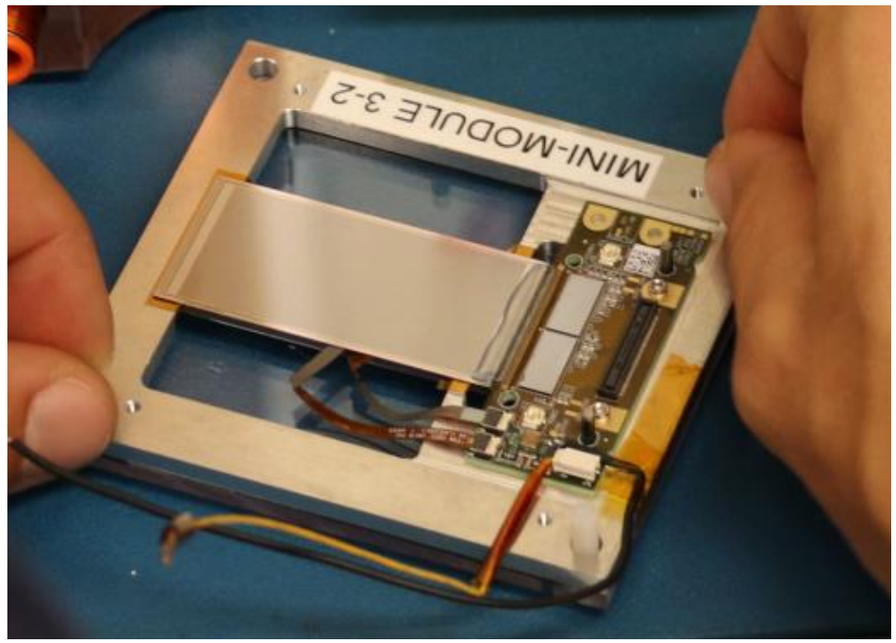
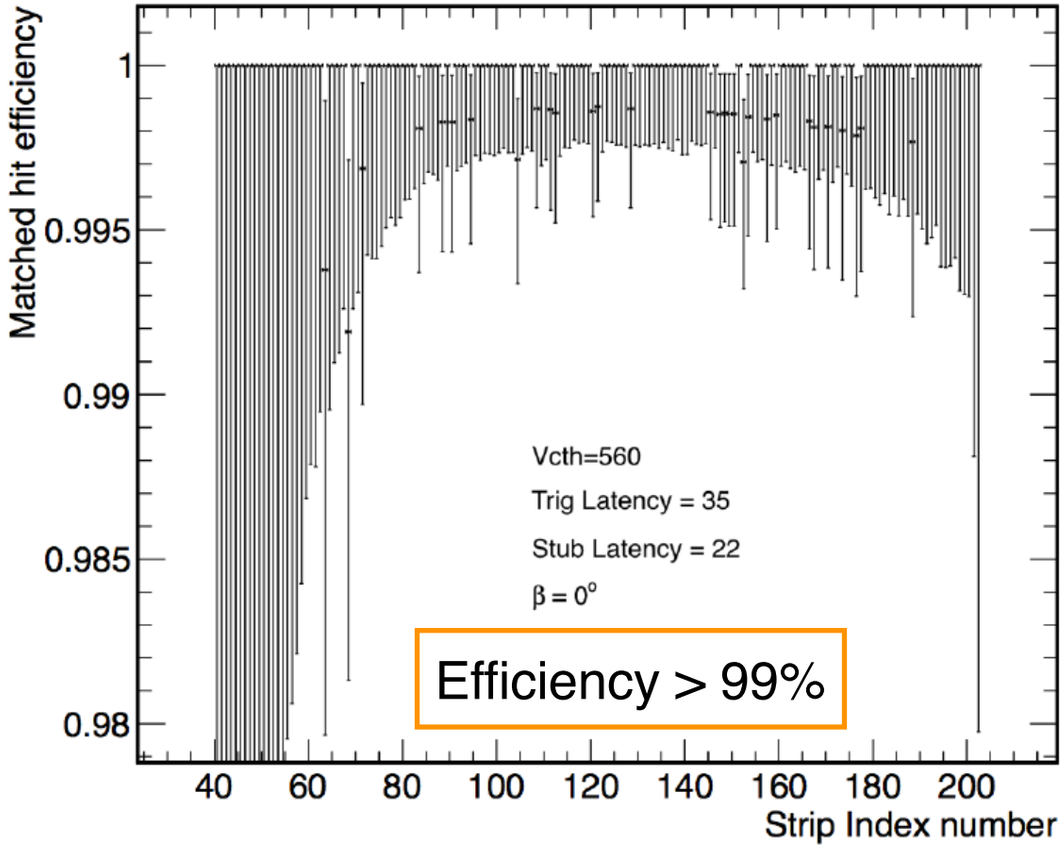
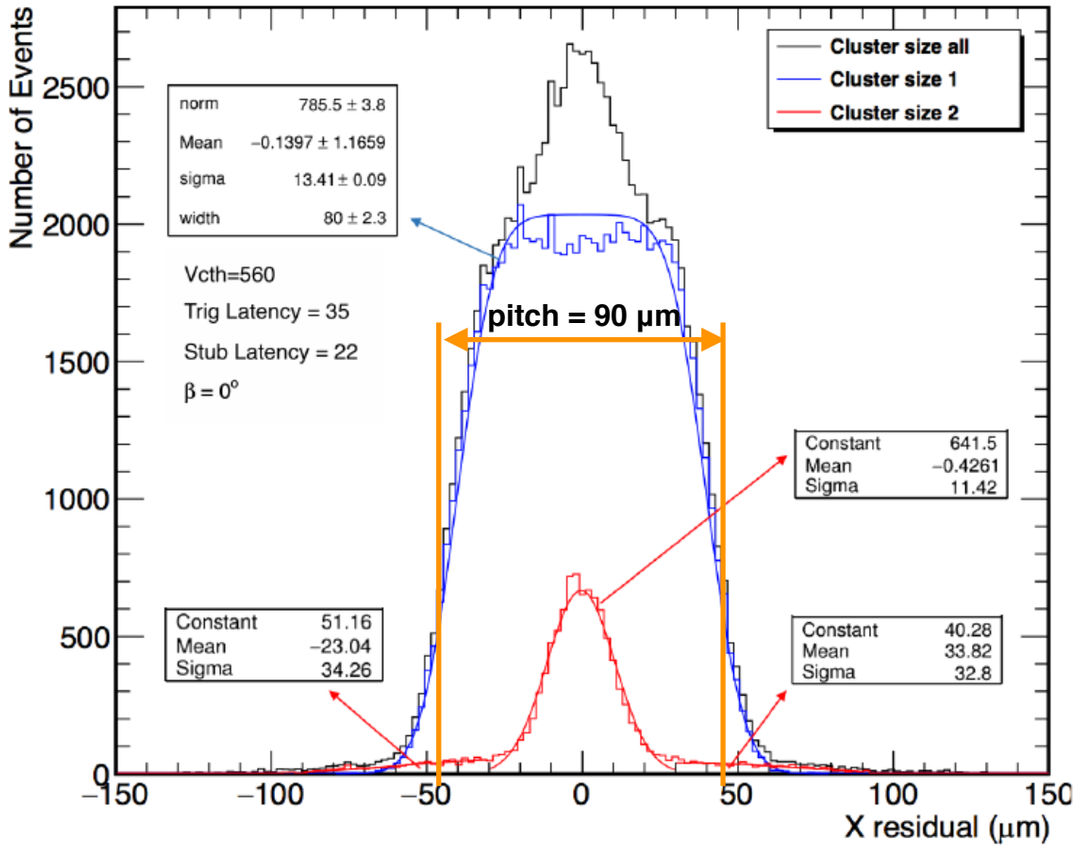
Status of the upgrade - 2S prototypes

- Mini-modules equipped with two CBCs and two small strip sensors stacked.
- Various beam test campaigns before and after irradiation carried out.
- Efficiency and resolution in agreement with the expectations.







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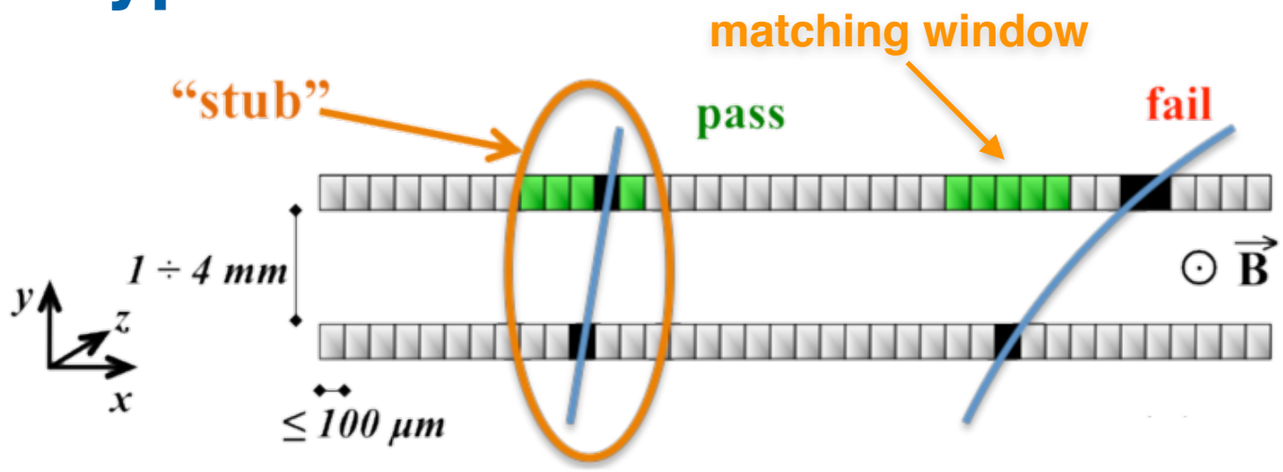
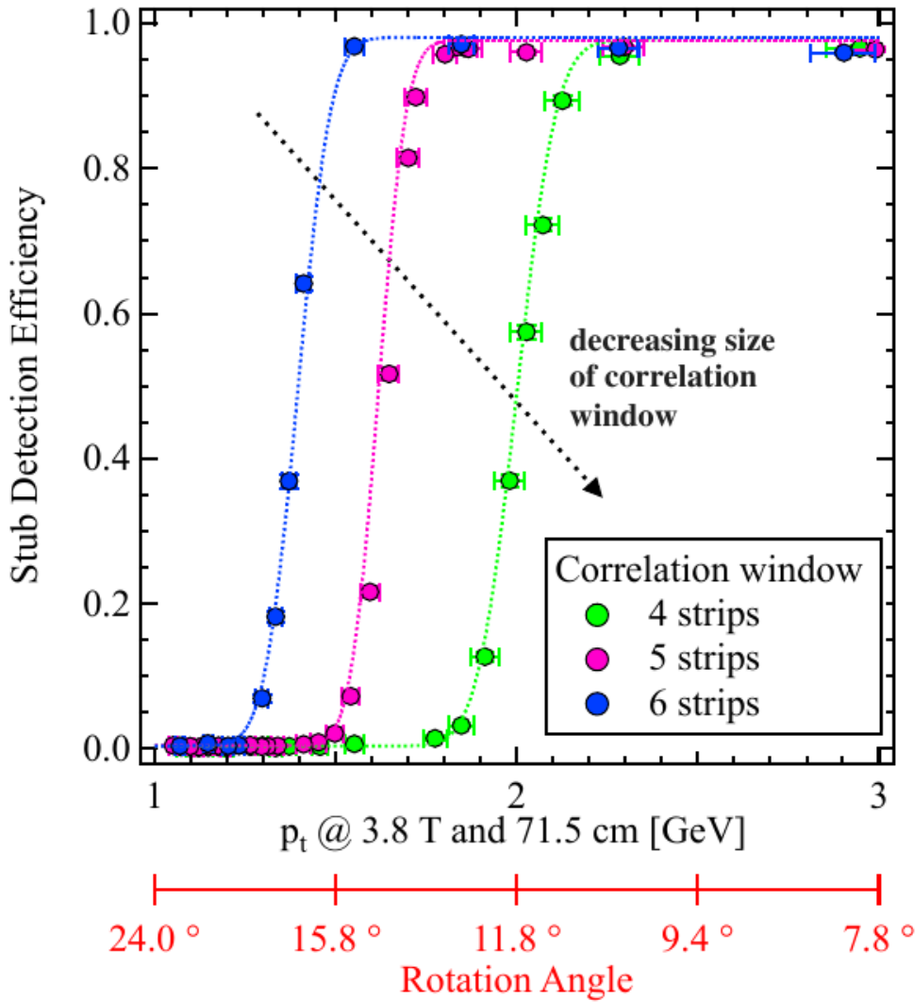
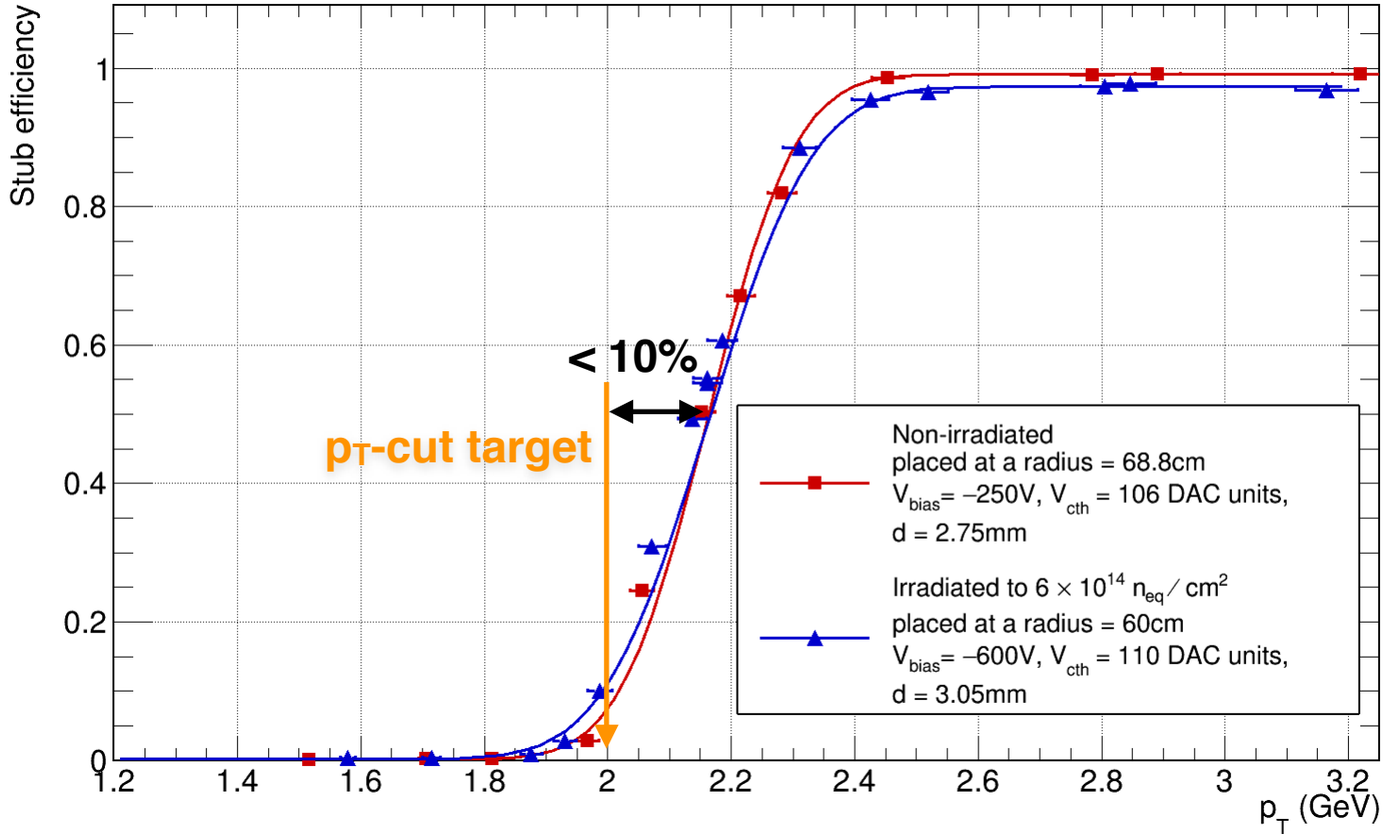
Status of the upgrade - 2S prototypes

- p_T cut is tuned by varying the matching window size.
- Prototype irradiated to 6x10^{14} n_{eq}/cm^2, twice the expected fluence for the full HL-LHC data taking



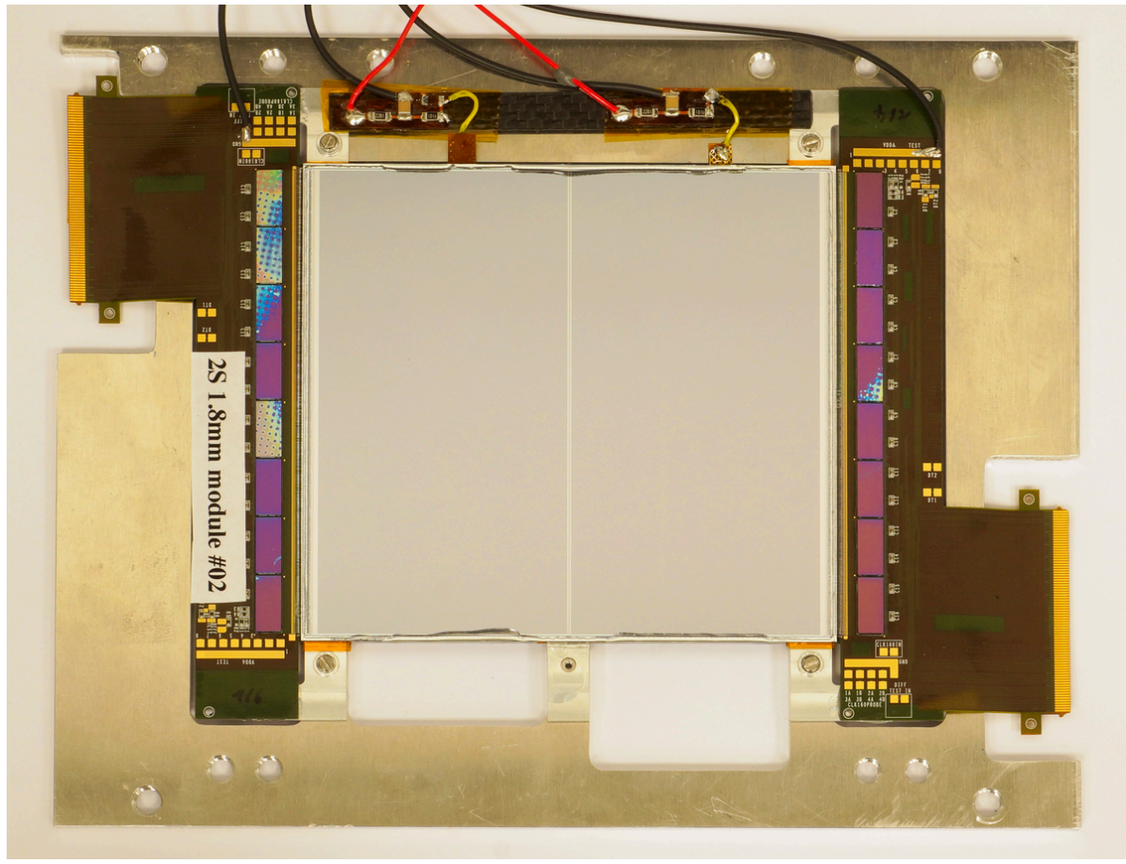


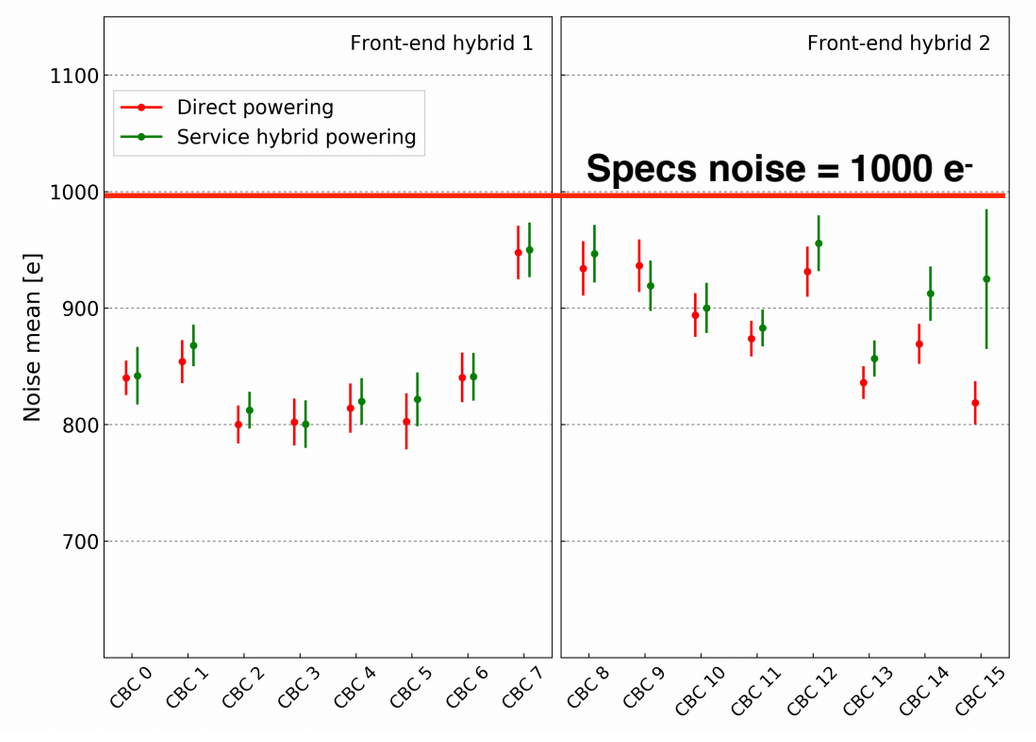


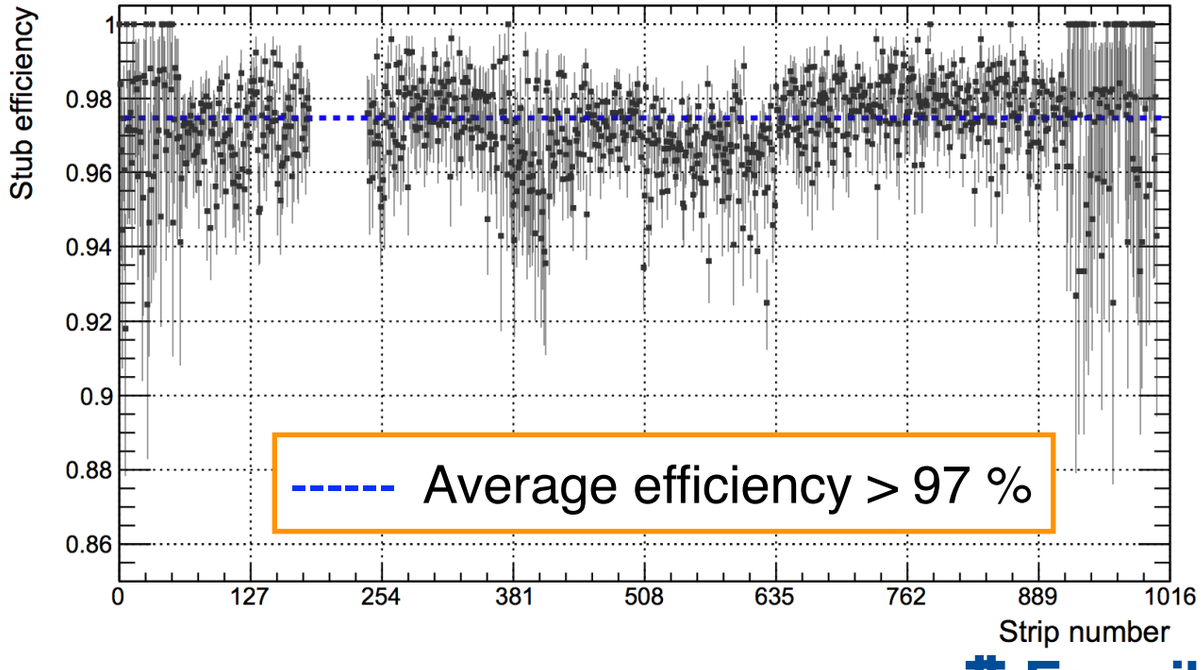
After irradiation the efficiency is still very high and the threshold in p_T remains steep.

Status of the upgrade - 2S prototypes

- The mechanical aspect of large complexity, critical detector handling and assembly alignment.
- Full modules assembled in the various production centers to validate the procedures and gaining experience.
- Prototypes tested in laboratory and with beam showed good results.







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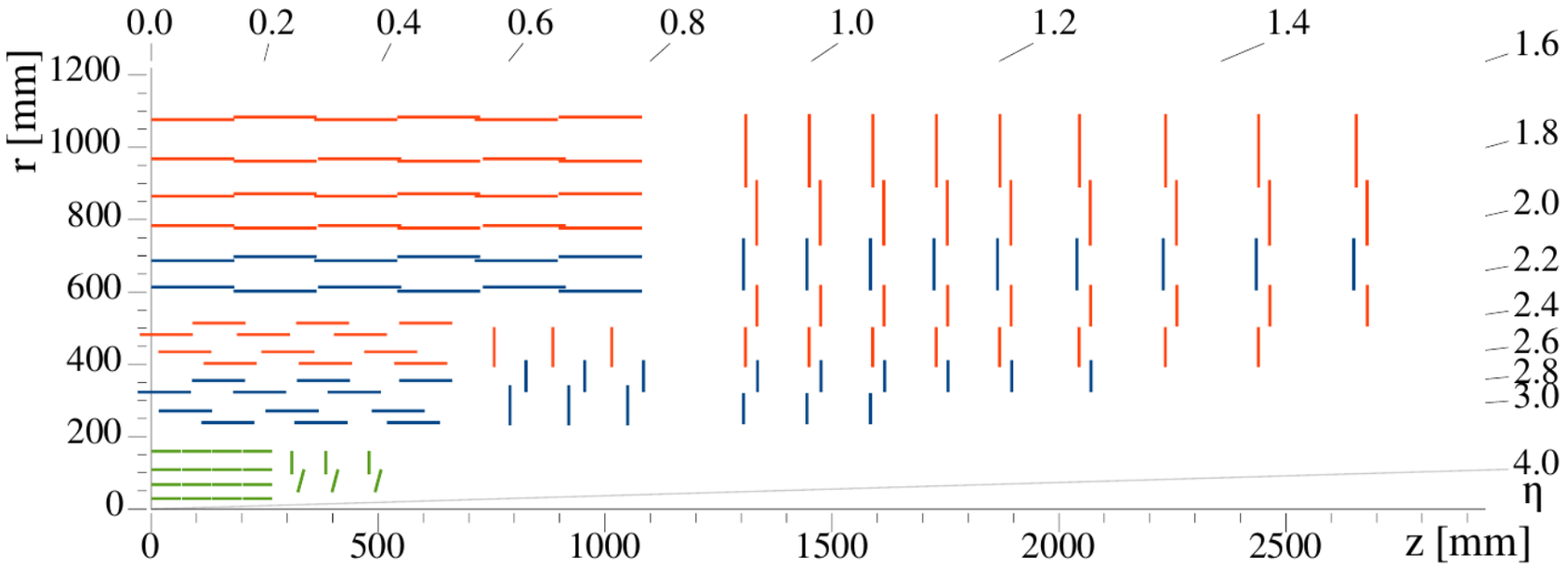
Conclusions

- The LHC will be upgraded in 2024 for the High-Luminosity data taking with great opportunities for physics but harsh challenges for the experiments.
- The CMS Outer Tracker will provide L1 tracking capabilities thanks to the p_T-modules.
- First MPA mini-modules (the “P” of PS) showed results compatible with the specs.
- 2S mini-modules showed excellent results in terms of efficiency, resolution and stub building functionalities.
- Full 2S modules assembled to validate the procedures with good results.

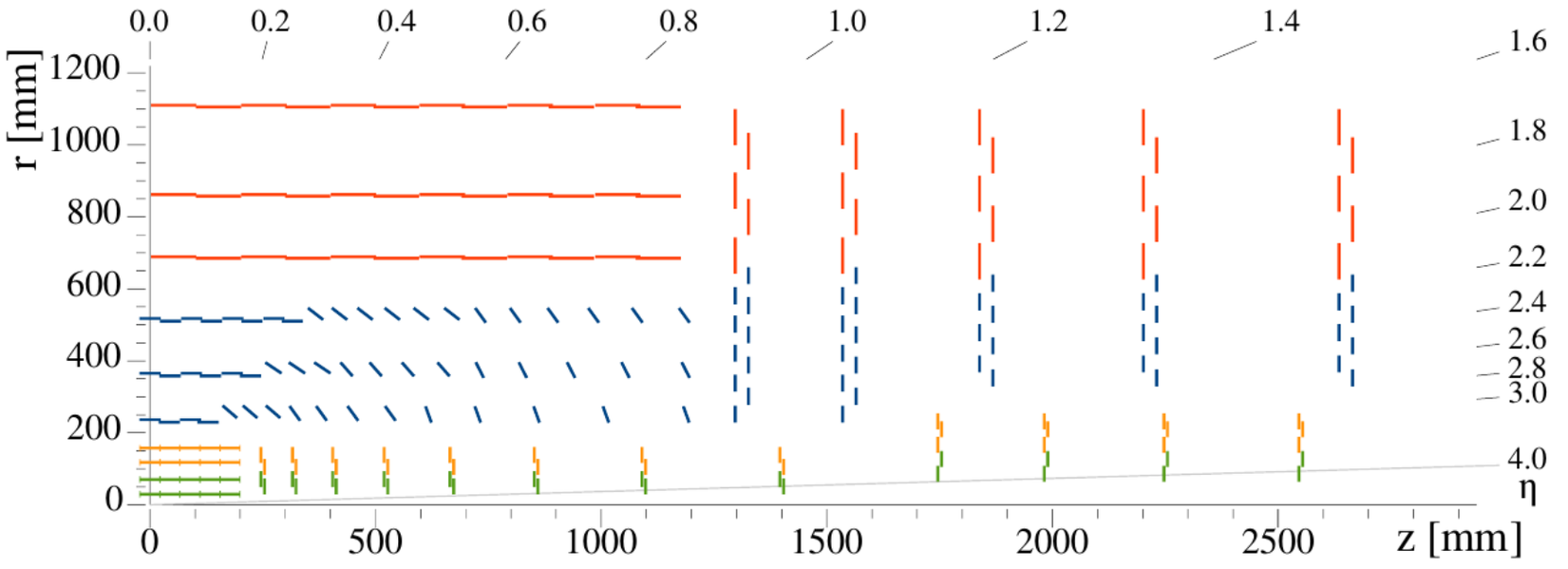
- Getting ready for pre-production!
  - Construction of 2250 modules plus 5% pre-production and 10% spare modules at Sidet
  - Design, module fabrication, and assembly of the Flat Barrel at Sidet
  - Construction of all macro-pixel-assemblies or MaPSAs

Backup - Tracker layout for HL-LHC

Phase 1 tracker



Phase 2 tracker



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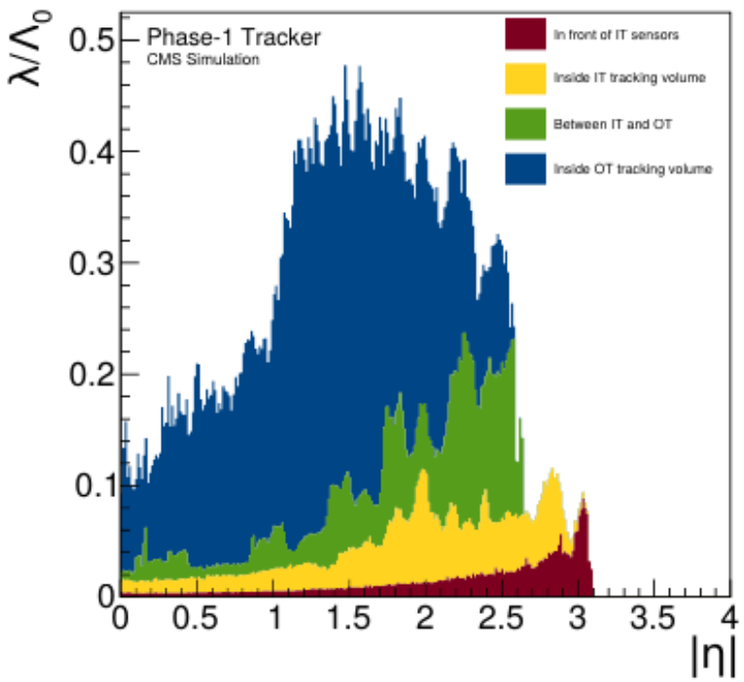
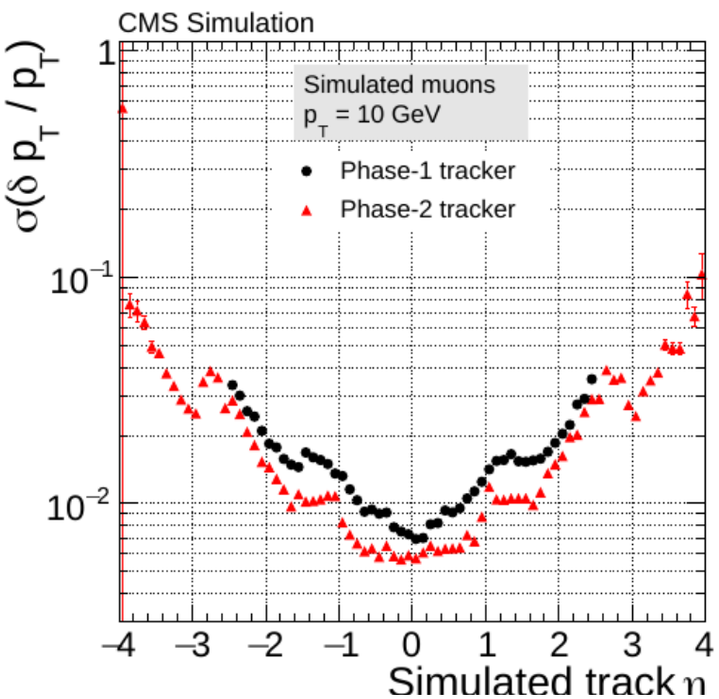
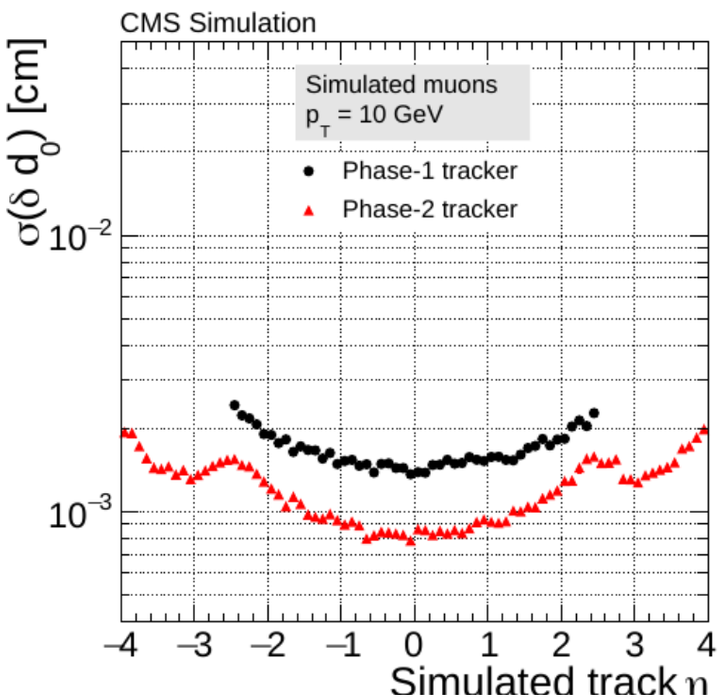
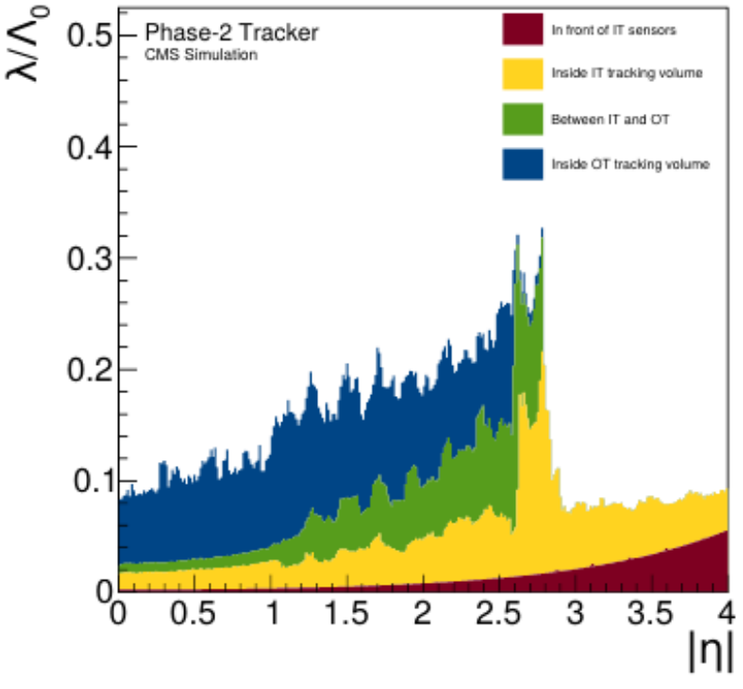
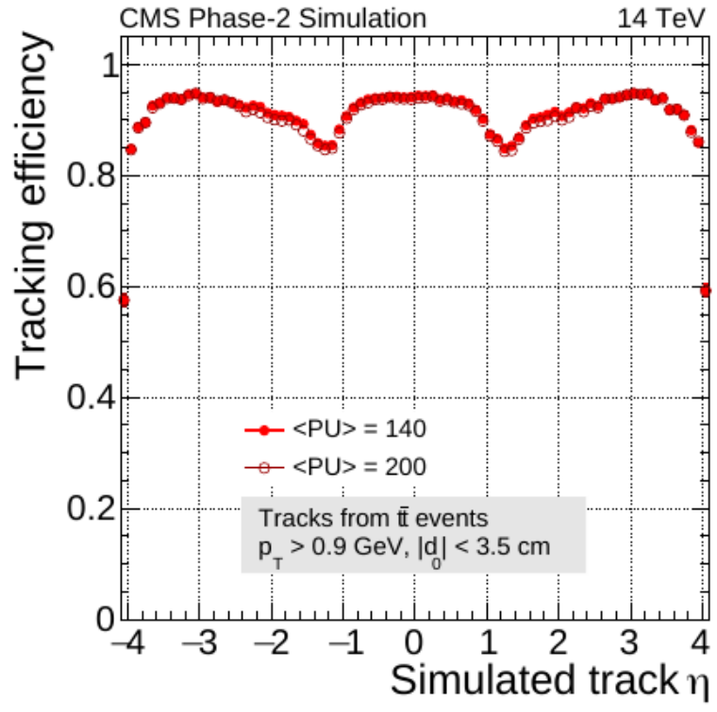
Expected performances

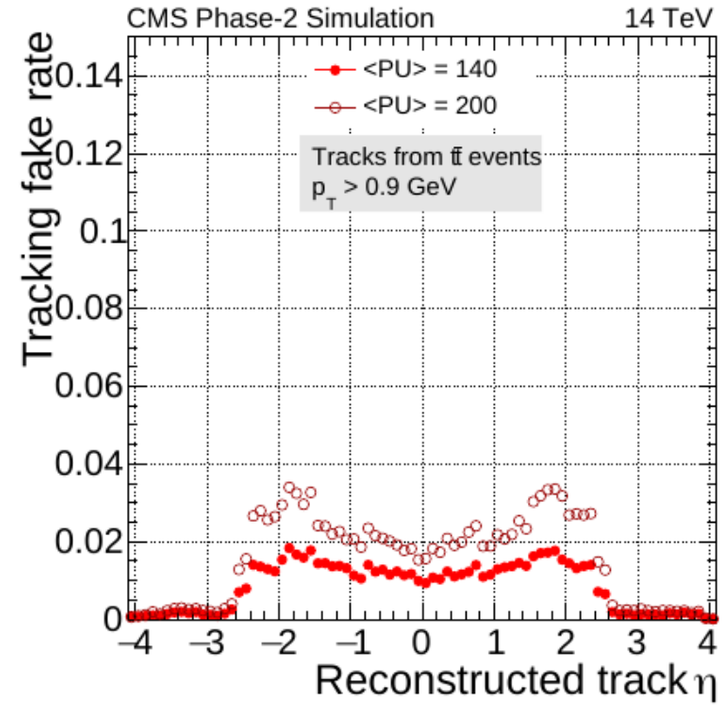












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